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The influence of moisture upon the formation of roots by cuttings of ivy

HARRIET RANDOLPH

When pieces of the leafy stem of English ivy (*Hedera Helix* L.) are kept for a time with one end immersed in water or in damp sand, roots generally arise on the part that is submerged. If the stem is then transplanted into soil, the new roots continue to grow and the piece of stem becomes an independent plant. This is the familiar method of raising new individuals from slips.

These new roots may arise close to the cut end of the stem and in any one or in all of the submerged internodes above the cut. They are white and thickly covered with root-hairs. Their structure in cross-section is shown in figure 3. When transplanted, the structure of the part subsequently formed in the soil is very like that of the part that grew in water.

The holdfast-roots, *i. e.*, the outgrowths along the side of the stem by which the ivy clings to the wall, under ordinary circumstances remain unchanged in the water. If kept there for a long time, the outer tissues decay and fall away, leaving the thicker-walled central part.

Experiments to be described below have shown that under varied conditions the ivy may send out roots that differ in some respects from these two kinds.

If the slips in water are kept in a greenhouse or in a room where the air is somewhat more moist than the normal, it sometimes happens that growth is set up in the submerged holdfast-roots. Delicate white outgrowths covered with root-hairs make their appearance either (1) from the tip of the holdfast-root, or (2) from some point along its side, or (3) from the matted felt-like complex formed by the growing together of several holdfast-roots as they attached themselves to a wall. (Figure 1, *hra*, showing near the lower end of the stem absorptive roots arising from the side of the holdfast mat that had adhered to the stone.) These secondary outgrowths from the holdfast-roots may occur in any of the submerged internodes and without any apparent relation to

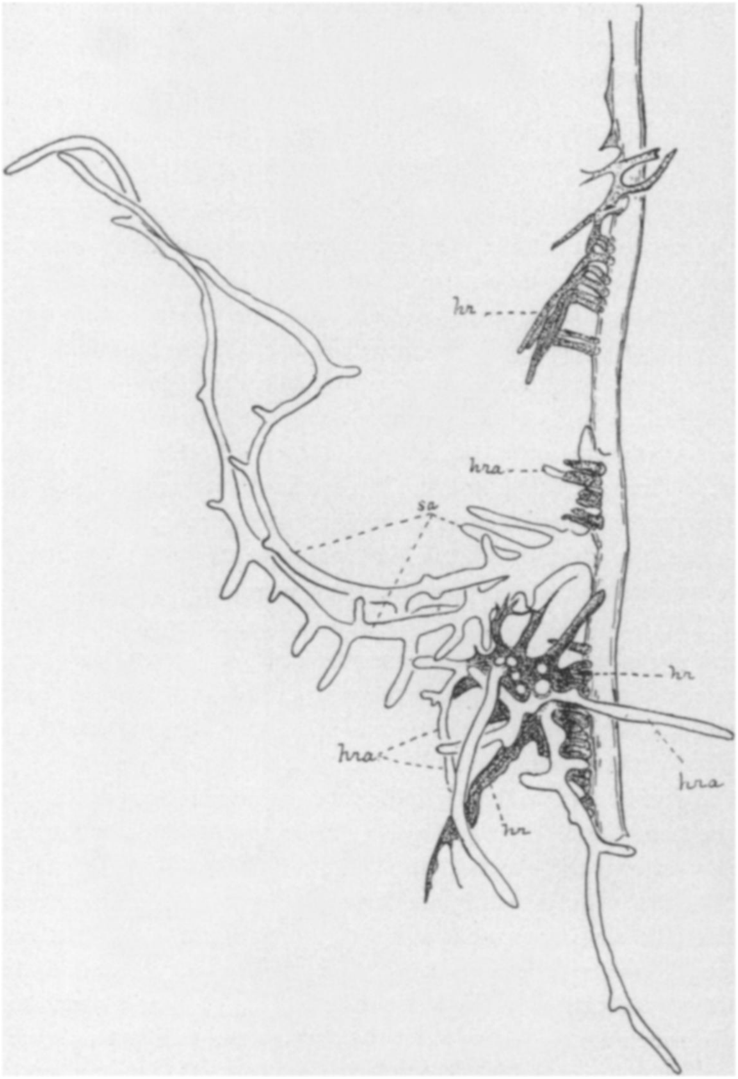

FIGURE I. Traced from a photograph of ivy stem grown in a greenhouse in air slightly moist, showing the part of the stem that was under water. The lowest group of holdfast-roots (*hr*) had grown together, forming a felt-like mat whose distal surface, which had adhered to a wall, is turned toward the observer. From this distal side of the mat of holdfast-roots absorptive roots (*hra*) have arisen. A group of absorptive roots springing from the stem (*sa*) slightly above has been turned aside in order to leave the view of the holdfast-roots and their outgrowths unobstructed.

the presence or absence of absorptive roots from the stem. The secondary roots increase in length and are not distinguishable in appearance from the ordinary roots that arise from the stem.

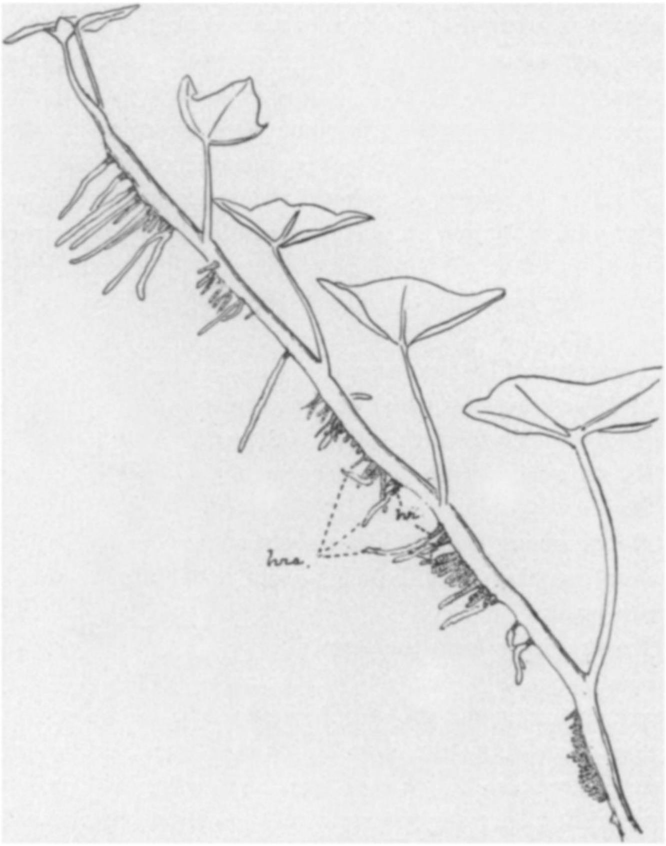

FIGURE 2. Traced from a photograph of young stems growing in water in air saturated with moisture, cut in May when the holdfast-roots had begun to appear. Many of the holdfast-roots (*hr*) have continued to grow, but the part grown in saturated air (*hra*) has a different structure from that of the original holdfast-roots. The holdfast-roots nearest the growing end of the stem had scarcely appeared when the stems were cut.

If the slips in water are kept in an atmosphere saturated with moisture, roots sometimes arise from the part of the stem that is in the air, above the surface of the water in which the stems are standing. They appear to arise indifferently on stems with leaves and on stems from which the leaves had been cut off at the beginning of the experiment. These roots, like those above mentioned that grow from holdfast-roots, have the same appearance as roots that grow from stems under water.

If young stems with green holdfast-roots beginning to grow out are kept in a vessel of water in saturated air, the growth of the holdfast-roots that are above the water continues, but the part that has grown in saturated air is white and covered with root-hairs.

In one instance, occurring in some slips growing in a pot of damp sand in the greenhouse, roots appeared on the sides of the stems about two centimeters above the sand and grew out and downward obliquely into it. They resembled the prop roots of Indian corn.

Thus under varying conditions the English ivy has seven classes of roots:

1. The roots of the seedling.
2. Holdfast-roots by which it clings to walls.
3. Roots arising from the stem under water.
4. Roots arising from the stem in an atmosphere saturated with water.
5. Roots arising from holdfast-roots under water.
6. Roots arising from holdfast-roots in an atmosphere saturated with water.
7. Roots arising from the stem over moist sand in greenhouse air.

I have not examined the structure of roots of class 1.

In the other roots the same kinds of tissues are present, but there are differences in the size or in the number of certain cells that give a characteristic appearance to sections of the different roots.

The structure in general is as follows: The epidermis consists of two (in one case of three) layers, with (or without) root-hairs; the cortical parenchyma is about five cell-rows in thickness; the endodermis surrounds the fibro-vascular bundles; and in the center there is a column of sclerenchymatous cells. Lying within the endodermis, next to it and also next or very near to the outer vessel of each bundle, are ducts lined by secreting cells. When the roots increase in thickness the ducts continue to lie next to the endodermis.

In the common roots that grow out in water from the stem (class 3) the parenchyma has very thin walls, and thus the epidermis and the endodermis are sharply differentiated from it. In these roots, and in the roots that grow out from them after transplantation into earth, the secreting cells are about the size of the cells of the surrounding tissue. The secreting cells contain dense protoplasm and the ducts are empty. The sclerenchyma of the central column is shaped in transverse section like a sharp-pointed star (figure 3).

In the following kinds of roots the ducts have contents * and the central sclerenchyma cells are more numerous and in section resemble a regular pentagon. Hence the phloëm is farther removed from the center of the stem and the endodermal ring is larger than in common water roots, etc.

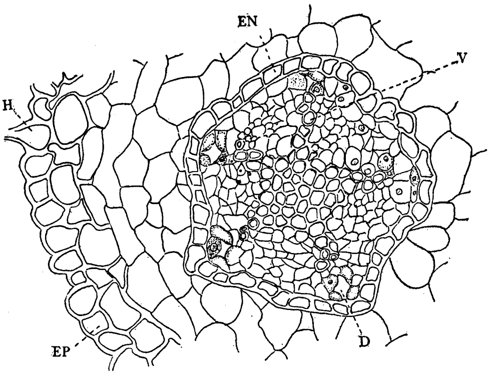

FIGURE 3. Cross-section of absorptive root springing from the submerged part of the stem of ivy in water. *d*, duct ; *en*, endodermis ; *ep*, epidermis ; *h*, hair ; *v*, vessels.

In the holdfasts (class 2) the epidermis is from two- to three-layered, and root-hairs are entirely absent or sparse (figure 4).

Adjoining or very near to each set of vessels of the holdfast-roots and on their peripheral side is a duct containing a yellowish substance and bounded in cross-section by four cells. This substance is probably the cement by which the holdfast-roots adhere to foreign surfaces.† Ducts are present in the cortical parenchyma of the stem, with contents apparently similar but with walls consisting of a greater number of cells (figure 5).

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* The roots here described were all preserved in Flemming's solution.

† DARWIN, C. Climbing plants 187, 188.

In roots arising from holdfasts (class 5) the secreting cells are from two to three times the size of the largest cells of that region, and their ducts, like those of the holdfasts contain a yellow substance.

In the roots arising from the stem in air saturated with moisture (class 4) the epidermis is without root-hairs, the secreting cells of the ducts are about four times the size of the largest of the neighboring cells, and the ducts contain a brownish-black substance.

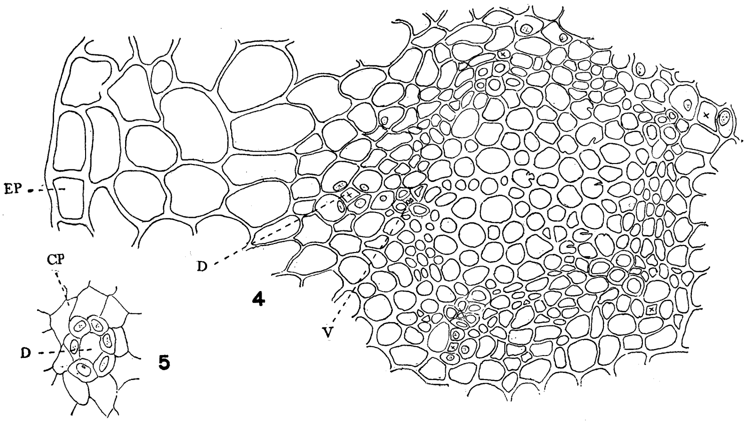

FIGURE 4. Cross-section of holdfast-root of ivy. *d*, the cavity of the duct (also marked ×); in some cases there are six sets of vessels; *ep*, epidermis; *v*, vessels.

FIGURE 5. From the stem of ivy, showing duct in the cortical parenchyma. It lies near the fibro-vascular bundles. *cp*, cortical parenchyma; *d*, duct.

In the corn-like roots which arise from the stem (class 7) the secreting cells are much larger than any of the surrounding cells, and the ducts (like those of the roots arising from the stem in air saturated with moisture) have brownish-black contents. Granules of this substance collected on the inner sides of the cell-walls bordering on the lumen were especially well seen in longitudinal section. These roots contain from six to nine vessels in a bundle, while in all the other kinds of roots the number varies from two to five.

The ivy, *Hedera Helix* L., is the typical example of dimorphism of shoot and leaf. * The possession of absorptive roots growing out into moist air from the holdfast-roots brings the ivy into relation with the tropical vines which send down roots to the soil from different points along the climbing stem. These roots (Nährwurzel) convey to the upper parts of the vines a supply of water for which their thin stems are wholly inadequate.* Roots of this kind arising from the stem are believed to have their phylogenetic origin from holdfast-roots (Haftwurzel).† The roots that now grow out from the holdfast-roots of the ivy may represent an early stage of this process. The presence of large numbers of root-hairs is evidence that these secondary roots that spring from the stem have the function of absorption. As in the case of the tropical vines, ‡ there is in the ivy a difference in structure between the absorptive roots and the holdfast-roots.

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*SCHENCK, H. Beiträge zur Biologie und Anatomie der Lianen 1: (SCHIMPER, A. F. W. Botanische Mittheilungen aus den Tropen 4:) 93, 94. 1892.

The presence of secondary absorptive roots in the ivy brings this species into closer relation with other members of its family (*Araliaceae*) in the tropics, and with epiphytes in general. Schenck § states: "In fast allen Familien oder Gattungen mit wurzelkletternden Lianen begegnen uns gleichzeitig auch epiphytische Formen. So enthalten die Araliaceen in den Tropen epiphytische Holzgewächse. . . . Wurzelkletterer und Epiphyten sind verwandte Vegetationsformen, und aus ersteren können sich leicht letztere herausbilden, falls die Verbreitungsmittel der Früchte oder Samen entsprechende sind. . . . In der That giebt es ja auch viele kreichende oder wurzelkletternde Epiphyten, welche in manchen Eigenthümlichkeiten mit den echten Wurzelkletterern übereinstimmen."

BRYN MAWR COLLEGE.

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* SCHENCK, *loc. cit.* 106.

† GOEBEL, K. Organographie der Pflanzen 488. 1900.

‡ GOEBEL, *loc. cit.* 487.

§ *Loc. cit.* 111.